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**BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES**

Application Number: 10/623,674

Filing Date: July 21, 2003

Appellant(s): BURCH ET AL.

Steven D. Burch and John C. Fagley
For Appellant

EXAMINER'S ANSWER

This is in response to the appeal brief filed 27 June 2005 appealing from the Office action mailed 9 February 2005.

(1) Real Party in Interest

A statement identifying by name the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

The examiner is not aware of any related appeals, interferences, or judicial proceedings, which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

(3) Status of Claims

The statement of the status of claims contained in the brief is correct.

(4) Status of Amendments After Final

The appellant's statement of the status of amendments after final rejection contained in the brief is correct.

(5) Summary of Claimed Subject Matter

The summary of claimed subject matter contained in the brief is correct.

(6) Grounds of Rejection to be Reviewed on Appeal

The appellant's statement of the grounds of rejection to be reviewed on appeal is substantially correct. The changes are as follows: The appellant states claims 1-3, 6-9 & 28 are rejected under Grasso in view of Bloomfield and Mugerwa. The Mugerwa reference is used as evidence not as an "in view of" reference. The appellant also states claims 10 & 26 are rejected under Grasso in view of Bloomfield and Baukal Jr. Like the Mugerwa reference, Baukal Jr. is used as an evidentiary reference.

(7) Claims Appendix

The copy of the appealed claims contained in the Appendix to the brief is correct.

(8) Evidence Relied Upon

| | | |
|--------------|-----------------|---------|
| 2001/0004500 | Grasso et al. | 6-2001 |
| 3,982,962 | Bloomfield | 9-1976 |
| 4,670,359 | Beshty et al. | 6-1987 |
| 6,375,924 | Towler et al. | 4-2002 |
| 2002/0004152 | Clawson et al. | 1-2002 |
| 5,360,679 | Buswell et al. | 11-1994 |
| 5,302,470 | Okada et al. | 4-1994 |
| 6,331,366 | Van Dine et al. | 12-2001 |
| 2002/0081466 | Hallum et al. | 6-2002 |
| 2002/0015870 | Cownden et al. | 2-2002 |
| 2002/0160239 | Cutright et al. | 10-2002 |
| 2002/0046889 | Kunitake et al. | 4-2002 |
| 2002/0177016 | Okamoto | 11-2002 |
| 2003/0027025 | Van Dine et al. | 2-2003 |

Mugerwa, M.N. et al, eds. *Fuel Cell Systems*, 1993, Plenum Press New York.

Pgs. 202,228,229.

Baukal, Jr., C. E. *Heat Transfer in Industrial Combustion*. CRC Press. Boca Raton. 2000. Sections 2.2.3, 8.414.

Anthony R. Eggert et al., *Characteristics of an Indirect-Methanol Fuel Cell System*, American Institute of Aeronautics & Astronautics, 2000-3040, Pgs. 1326-1332

(9) Grounds of Rejection

The following ground(s) of rejection are applicable to the appealed claims:

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

- (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

Claims 1-3 & 6-9 are rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al (US 2001/0004500) in view of Bloomfield (3,982,962), as evidenced by Mugerwa et al. (*Fuel Cell Systems*).

The Grasso reference teaches a fuel cell power plant in which a reformer (Figure 1, 58: applicant's primary reactor), preferably an autothermal reformer but possibly a conventional steam reformer (pg. 4, [0033]), receives a reactant stream comprising fuel, air, and steam (Figures 1, 56, 54) that is used to produce a reformed fuel (Figures 1, 60: applicant's reformat). The reformed fuel is sent through a water shift reactor (Figure 1, 64: applicant's water gas shift (WGS) reactor) to a fuel cell or fuel cell stack (Figure 1, 14: applicant's HT-PEMFC) with an electrolyte such as a proton exchange membrane (PEM) (pg. 3, [0030]) where it is used to generate electricity. It is noted that applicant requires a high temperature proton exchange membrane fuel cell (HT-PEMFC); this requirement is met in the Grasso reference's "electrolyte such as a proton exchange

membrane (PEM)" (pg. 3, [0030]). The power plant also includes a catalytic burner (Figures 1, 40: applicant's catalytic combustor) that oxidizes excess reformed fuel from the anode exhaust of the fuel cell (Figures 1, 42; pg. 4, [0034]: applicant's excess hydrogen). The exhaust from this burner (Figures 1, 52) is sent to a steam generator (Figures 1, 50) to produce steam from a water supply, including a portion of the cooling stream exiting the fuel cell (Figure 1, 84), for the reforming reaction and, as such, provide the reactant (Figure 1, 54) at a temperature appropriate for the reaction in the reformer. Additionally, the steam generator may be unnecessary as adequate water (interpreted as adequate in terms of quantity and quality; steam) may be supplied by fuel cell means (pg. 4, [0032]) and may be sent directly to the burner or reformer (pg. 4, [0034]).

However, the Grasso reference fails to teach a compressor to provide air to the fuel cell stack; anode, cathode and stack excess steam condensers; a heat exchanger between the primary reactor and WGS reactor for heating steam with reformatte heat; or the use of a catalytic combustor burning excess hydrogen to maintain the temperature in the primary reactor.

The Bloomfield reference teaches a fuel cell power plant containing a fuel cell thermal management portion (Figures 1, 25) in which water flows to cool the fuel cell. This water is at least partially vaporized (turned to steam) in this process (Col. 5, in 28-33). This steam then flows through several heat exchange operations including a heat exchanger (Figure 1, 72: applicant's primary reactor heat exchanger) positioned between the steam reforming reactor (Figure 1, 18: applicant's primary reactor) and the

shift converter (Figure 1, 16: applicant's WGS reactor) that transfers heat from the processed fuel (Figure 1, 70: applicant's reformate) to the steam stream from the thermal management portion of the fuel cell before it is mixed with fuel and fed to the steam reforming reactor. The power plant also includes a burner (Figure 1, 20: applicant's catalytic combustor) that oxidizes excess reformed fuel from the anode effluent gas of the fuel cell (Figure 1, 78, 82: applicant's excess hydrogen). The burner provides heat for the steam-reforming reactor by passing the burner effluent gases (Figure 1, 86) in a heat exchange relationship with the reactor (Col. 5, in 2-6). Mugerwa teaches that the reformer and fuel cell generate heat that can be used elsewhere in the fuel cell system; good design must ensure a high degree of heat integration, thereby enabling maximum fuel cell system efficiencies (Pg. 228-229).

Both Grasso and Bloomfield teach the use of steam generated in the fuel cell being divided for use between the reformer and the fuel cell cooling loop. Grasso teaches that a portion of the cooling water (Figure 1, 84) is diverted to the reformer (Figure 1, 58) through a steam generator (Figure 1, 50) after exiting the fuel cell. The remaining portion of the cooling water (Figure 1, 72) is recycled through the cooling loop. In some cases, the steam generator is unnecessary because "adequate water" (interpreted as adequate in terms of quantity and quality) is supplied by the fuel cell. The water may be sent directly to the reformer (pg. 4, [0032], [0038]). Bloomfield teaches water that is at least partially vaporized as it is sent through the fuel cell in a heat exchange relationship. This water/steam then flows through several heat exchange relationships where it is completely vaporized and superheated before being delivered

to a valve (Figures 1, 96). This valve permits the amount of steam necessary for the reforming reactor into stream 66; the remainder of the steam is delivered back to the cooling loop via a turbine and condenser in order to feed the water to the cooling loop in the liquid phase (Col. 5, in 28-60). Although neither reference speaks to the fraction of the steam stream that is recondensed for use in the fuel cell cooling loop or the fraction sent to the reformer, one of ordinary skill in the art would be familiar with the amount of steam needed for the reforming reaction and for adequate cooling of the stack.

The Bloomfield reference teaches air cooled condensers (Figures 1, 80, 54) for both the anode and cathode exhaust streams (Figures 1, 78, 52) and the remainder of the steam (Figures 1, 104) not needed in the reforming reactor (applicant's anode and cathode exhaust condensers and excess steam condenser). These condensers recover water to be recycled to the fuel cell cooling loop. Bloomfield also discloses an air stream delivered to the fuel cell cathode (Figures 1, 50) via a compressor (Figures 1, 38) with an air inlet (Figures 1, 44). One of ordinary skill in the art of plant design and optimization would recognize the potential to recycle the air from the condensers to the compressor inlet, as evidenced by Mugerwa, "the greater the degree of interaction possible between the fuel cell and fuel processing subsystems the better the combined performance and system design will be" (Pg. 202). Doing so would also reduce the utility cost of the fuel cell power plant by reducing the external supply of air.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have combined the reformer with a reactant stream comprising steam, air, and fuel to produce a reformed fuel; WGS reactor; catalytic

combustor for anode exhaust; and PEM fuel cell stack taught by Grasso et al. with the thermal management portion of the fuel cell for generating steam for use in the reformer; heat exchanger for transferring heat from the reformed fuel to the generated steam; anode exhaust burner effluent gases for heating the reformer reactor; and anode and cathode exhaust stream and excess steam air-cooled condensers and air compressor to feed the fuel cell (with condenser air used to supply the compressor as generally known in design and optimization) as taught by Bloomfield and the division of the steam stream generated by the fuel cell to the reformer and cooling loop taught by both references in order to reduce the utility cost associated with operating the fuel cell power plant. The use of the water/steam from the thermal management portion of the fuel cell to provide water for the reformer and the cooling loop, use of the processed fuel heat to heat the water/steam, use of a catalytic combustor to burn the anode exhaust/excess hydrogen for heating the reformer reactor, use of condensers to recover water from the anode and cathode exhaust streams and excess steam stream for use in the cooling loop, and use of the cooling air in the condensers as the feed to the air compressor are economically advantageous strategies as they reduce the overall utility cost associated with this power plant by decreasing the amount of external water and air that must be supplied and the material or equipment that would be needed to provide heat, and they allow for efficient thermal management within the fuel cell power plant.

Claim 4 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al.

(Fuel Cell Systems) as applied to claim 1 above, and further in view of Beshty et al. (4,670,359).

The Grasso and Bloomfield references teach the elements of claim 1, including a catalytic burner that burns anode exhaust of the fuel cell (applicant's excess hydrogen) but fail to disclose a superheat heat exchanger to heat the reactant steam before introduction to the primary reactor using heat energy from a catalytic combustor.

Beshty teaches a mixture of water and methanol fuel (Figures 2, 26A) fed to a heat exchanger (Figures 2, 26) where it is superheated before continuing to the reformer (Figures 2, 23: applicant's primary reactor). A burner (Figures 2, 47) supplies combustion products (Figures 2, 49: applicant's heat energy) to the heat exchanger for heat energy to be transferred to the water/fuel mixture by burning the anode exhaust of the fuel cell (applicant's excess hydrogen) (Col. 6, ln. 64 – Col. 7, ln. 3). The superheated water/fuel mixture contains enough sensible heat for the endothermic reforming reaction to proceed with little, if any, external heat input (Col. 6, ll. 10-14).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield a heat exchanger for superheating the fuel and water to be fed into a reformer using the exhausted combustion products from a burner that burns the anode exhaust of the fuel cell as taught by Beshty et al., said burner being a catalytic burner as taught by Grasso et al., for the purpose of reducing the external heat input necessary to stimulate the endothermic reforming reaction and for efficient thermal management within the fuel cell power plant.

Claim 5 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Towler et al. (6,375,924).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to disclose a WGS reactor heat exchanger in fluid communication between a WGS reactor and the HT-PEMFC stack adapted to heat steam before being used in the primary reactor with the heat energy of the reformat. It should be noted that the phrase "adapted to" is interpreted as "capable of."

Towler discloses a shift effluent cooler (Figure 1, 61: applicant's WGS reactor heat exchanger) receiving a shift effluent stream (Figure 1, 60: applicant's gaseous reformat) from a shift reaction zone (applicant's WGS reactor) where it heats and partially vaporizes, by indirect heat exchange, a deionized water stream (Figure 1, 40; Col. 12, ll. 16-27). The shift effluent stream then continues to the fuel cell (Figure 1; streams 60', 71, fuel cell 72). While the Towler reference does not teach that the water stream is that which has been used in cooling the fuel cell, the shift effluent cooler would be capable of receiving and heating such a stream in place of the deionized water stream disclosed. The cooler works to decrease the temperature of the effluent stream to effective oxidation conditions and to heat and partially vaporize the water stream.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included a heat exchanger as taught by Towler et al. to heat the water/steam being sent to the reformer between the WGS reactor and the fuel cell stack taught by Grasso et al. and Bloomfield with reformat heat so that less additional equipment and heating utilities would be necessary for efficient thermal management within the fuel cell power plant.

Claim 10 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Clawson et al. (US 2002/0004152 A1) as evidenced by Baukal, Jr. (*Heat Transfer in Industrial Combustion*).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a catalytic combustor in fluid communication with a combustor air preheat exchanger which is adapted to receive heat energy from combustor exhaust and to preheat air used in the catalytic combustor.

Clawson et al. teach a catalytic burner (Figures 1, 14: applicant's catalytic combustor) that receives an air and steam stream, a fuel stream, and recycled anode exhaust (Figures 1, 12, 14, 16). The air/steam stream has been heated in a heat exchanger (Figures 1, 34: applicant's air preheat heat exchanger) with heat energy from the catalytic burner exhaust stream (Figures 1, 30: applicant's burner exhaust). This heat exchange serves to recover most of the heat from the burner exhaust and prepare

it for condensation to recover water (pg. 5, [0066]). Baukal, Jr. teaches that available heat in a combustion system is increased with oxidizer preheat temperature resulting in fuel savings (2.2.3 Available Heat).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included the catalytic burner and heat exchanger as taught by Clawson et al. in the fuel cell power plant as taught in the Grasso et al. and Bloomfield references in order to recover and use the excess hydrogen in the anode exhaust stream, cool the combustor exhaust before discharging it from the plant, and reduce the fuel and utility cost associated with the operating the fuel cell power plant.

Claims 11 and 20 are rejected under 35 U.S.C. 103(a) as being unpatentable Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) over as applied to claim 1 above, and further in view of Buswell et al. (5,360,679).

With respect to claim 11, the Grasso and Bloomfield references teach the elements of claim 1 but fail to teach exhaust liquid separators to recover water from the anode and cathode exhausts from the HT-PEMFC.

The Buswell reference teaches that entrained water in the anode and cathode exhaust streams exiting the fuel cell stack is removed by water separators (Figure 1, 188 and 189), and the recovered water is sent to a water tank (Figure 1, 192) for use in the water recovery subsystem that, among other things, provides cooling water to the

cell, as it recycles water produced in the fuel cell stack (Col. 10, in 10-16, 38-43; Col. 5, in 14-25).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to include in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield the anode and cathode exhaust separators as taught by Buswell et al. for the purpose of recovering entrained water from the exhaust for use in other plant systems, and, therefore, reducing the amount of external water needed to carry out the operation and the associated utility cost.

Regarding claim 20, the Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a water/steam separator to remove excess water from the reformate before it is fed to the fuel cell stack.

Bloomfield also teaches that fuel cells perform better at higher reactant pressures (Col. 1, ll. 23-24). Buswell teaches a water separator (Figures 1, 182) that removes condensed water from the reformate fuel stream (Figures 1, 14) before it is sent to the fuel cell stack (Figures 1, 186). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to include a separator as taught by Buswell et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to remove condensed water from the reformate before its use in the fuel cell stack. The reaction at the anode of the fuel cell is gaseous and removal of condensed water before this reaction is advantageous from a reaction and efficiency standpoint, as taught by Bloomfield in that performance is better at higher reactant pressures.

Claim 12 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Okada et al. (5,302,470).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a stack coolant liquid separator to separate liquid water from the steam exiting the HT-PEMFC stack.

The Okada reference discloses a gas/water separator (Figures 1, 18: applicant's stack coolant liquid separator) for the cooling water circulated from the fuel cell stack where the water is recycled to the cooling loop and the steam is sent to the reformer (Col. 2, II. 52-60).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to add the gas/water separator for separation of liquid water and steam from the fuel cell cooling loop as taught by Okada et al. to the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to decrease the amount of external water necessary for plant operation and, in so doing, reduce the utility cost for the plant.

Claim 15 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Van Dine et al. (6,331,366).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a heat exchanger in which the reformatte is used to heat the anode exhaust before it is fed to the fuel cell stack.

The Van Dine reference teaches a second heat exchanger (Figures 1, 62: applicant's anode exhaust preheat heat exchanger) in which the anode exhaust (Figures 1, 42) is heated by the reformed fuel (Figures 1, 54: applicant's reformatte). The reformed fuel then continues to the fuel cell and the anode exhaust is combusted in a catalytic burner. Preheating the anode exhaust allows for efficient combustion in the burner so that the exhaust stream leaving the burner is non-flammable (Col. 13, ll. 7-13 and Col. 7, ll. 18-22).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield a heat exchanger for providing greater heat input to the anode exhaust by the reformed fuel in order to more efficiently combust the anode exhaust in the combustor and produce a non-flammable combustor exhaust stream as taught by Van Dine et al. This heat exchanger also provides heat integration within the plant thereby reducing utility costs and efficiency for the plant. The production of a non-flammable combustor exhaust stream is also environmentally advantageous.

Claims 16 and 29 are rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by

Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Hallum et al. (US 2002/0081466) and Cownden et al. (US 2002/0015870 A1).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach an anode stoichiometry. The Hallum reference teaches that the fuel (hydrogen) and air flow to the fuel cell stack must be sufficient to meet appropriate stoichiometric ratios to meet a given output power (pg. 1, [0005]); that is, the fuel feed is 100% of the theoretical fuel needed for the reaction, or an anode stoichiometry of 1.0. Hallum also teaches that due to the nonideality of the fuel cell stack, not all of the fuel fed to the stack will react (pg. 5, [0006]) so the feed rate may need to be increased to effect better fuel and power efficiency.

Figure 3 A of the Cownden reference provides the flow rates of fluid streams during a steady-state operating mode (pg. 7, [0098]). Streams 13 and 14 are the hydrogen-rich fuel (anode inlet) and anode exhaust streams, respectively, as shown on Figure 2. From the entries for these streams in the H₂ (lb mol/h) column of the table shown in Figure 3A (column 5), the amount of excess hydrogen can be calculated:

$$\text{H}_2 \text{ used in fuel cell anode reaction (theoretical hydrogen)} = \frac{\text{H}_2 \text{ in (stream 13)} - \text{H}_2 \text{ out (stream 14)}}{(17.90 - 3.56) \text{ lbmol/hr}} = 14.34 \text{ lbmol/hr}$$

$$\% \text{ excess H}_2 \text{ fed to anode} = \frac{\{[(\text{H}_2 \text{ fed to anode}) \div (\text{H}_2 \text{ used in fuel cell anode reaction})] - 1.0\} \times 100\%}{[(17.90 \div 14.34) - 1.0] \times 100\%} = 25.6\%$$

The Cownden reference therefore teaches 25.6% excess H₂ in the feed to the anode of the fuel cell. This is an anode stoichiometry of 1.26. Cownden also teaches that 50-90% of the hydrogen in the reformatre stream is consumed in the fuel cell stack (pg. 9,

[0130]), thus illustrating the need for feeding hydrogen in 10-50% excess, or an anode stoichiometry of 1.1 to 1.5, to achieve a desired output.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used an anode stoichiometry between 1.0 and 1.5 as taught by Hallum et al. and Cownden et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to reach the desired power output from the fuel cell.

Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Cutright et al. (US 2002/0160239 A1) and Okada et al. (5,302,470).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a ratio of steam to fuel carbon (S:C) for the primary reactor.

The Cutright reference teaches a molar ratio of water (steam) to methane (fuel carbon) in the reactor (reformer) in the range of 2.0 to 5.0 (pg. 3, [0026]).

The Okada reference teaches that S:C can affect the amount of carbon monoxide and hydrogen produced in the reforming reaction and deposition of carbon on the reforming catalyst. Decreasing S:C increases the hydrogen partial pressure, which in turn improves the efficiency of power generation in the fuel cell. This decrease in S:C also results in an increase of CO in the fuel gas that persists through shift reactions to remove it, and the CO poses a risk to the catalyst of the fuel electrode (applicant's

anode) of the fuel cell. Okada discloses ranges of S:C operation for Ru and Ni reforming catalysts: $S:C_{Ru} = 0.7\text{--}2.5$, $S:C_{Ni} = 1.5\text{--}3.5$, and also notes that S:C is commonly adjusted to more than 3 and more than 4 with the Ru and Ni catalysts, respectively (Col. 3, in 31 – Col. 4, in 30, 59–62).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used a steam to fuel carbon ratio between 2 and 5 as taught by Cutright et al. and Okada et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to improve the efficiency of power generation in the fuel cell while reducing the deposition of carbon on the reforming catalyst and fuel cell anode poisoning by CO.

Claims 18 and 30 are rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (US 2001/0004500) and Bloomfield (3,982,962) and evidenced by Mugerwa et al. (*Fuel Cell Systems*) as applied to claim 1 above, and further in view of Kunitake et al. (US 2002/0046889 A1).

The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a ratio of atomic oxygen in the airflow to carbon in the fuel flow (O:C) in the primary reactor.

The Kunitake reference teaches a method for removing carbon deposited on the steam reforming catalyst by adjusting the O:C ratio (Abstract). The O:C ratio in a fuel cell system in steady operating mode is held in the range 0.7–1.0, and the ratio is increased to execute the carbon removal process (pg. 4, [0051], examples). The value

of O:C for each example is different due to the conditions under which the carbon removal process is being run: Example 1, 2, 4 = 1.5, Example 3 ~ 1.75, Example 5 = infinity, Example 6 = peak of 4.8 (Figures 3B, 11B, 12B, 14B, 15B (pg 7, [0081]), 17B).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used an O:C ratio at steady conditions between 0.7 and 1.0 and while removing carbon from the reforming catalyst at an elevated O:C, such as 1.5 and 1.75 as shown in the examples of Kunitake et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to remove the deposited carbon from the reforming catalyst so that catalytic activity is not deteriorated by accumulation of carbon.

Claims 21, 22, and 24 are rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. (*Characteristics of an Indirect-Methanol Fuel Cell System*) in view of Okamoto (US 2002/0177016 A1).

Figure 1 of the Eggert reference shows a reformer (applicant's primary reactor) with a reactant stream of steam and fuel that generates a reformat. The reformat is fed to a PEM fuel cell stack (pg. 1327) that uses the reformat to produce electrical power. The fuel cell stack is water cooled, and the water and thermal management of the fuel cell maintains water self-sufficiency of the system, including water for steam reformation (pg. 1330). An evaporator (applicant's primary reactor heat exchanger) for transferring heat energy from the reformat to the reactant steam is positioned between the reformer and a water-gas-shift reactor. A catalytic burner (applicant's catalytic

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combustor) burns anode exhaust, fuel, and air to supply heat energy to the reformer and super heaters (applicant's superheat heat exchanger) for superheating the fuel and steam before they are mixed and reacted in the reformer. It is noted that applicant requires a high temperature proton exchange membrane fuel cell (HT-PEMFC); this requirement is met in the Eggert reference's proton exchange membrane (PEM) (pg. 1327). An HT-PEMFC employs a proton exchange membrane. The Eggert reference fails to disclose the addition of compressed air to the superheated stream.

Okamoto teaches a stream of air supplied to the reformer (Figure 1, 6: applicant's primary reactor) from a compressor in the air supply device (Figure 1, 11). The compressed air promotes water vapor reformate reactions and partial oxidation reactions (pg. 2, [0027]). Although the diagram does not show the superheated stream and compressed air stream being mixed before entering the reformer, they must be mixed prior to use within the reformer.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to mix the superheated reactant stream containing fuel and steam from the super heaters as taught by Eggert et al. with compressed air as taught by Okamoto in order to promote water vapor reformate reactions and partial oxidation reactions.

Claim 25 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. (*Characteristics of an Indirect-Methanol Fuel Cell System*) in view of Okamoto (US 2002/0177016 A1) and further in view of Towler et al. (6,375,924).

The Eggert and Okamoto references teach the elements of claim 21 as well as a CO clean-up unit consisting of a water-gas-shift reactor and preferential oxidation unit (applicant's CO-polishing stage) (pg 1327). However, the references fail to teach a WGS heat exchanger in fluid communication with the WGS reactor.

Towler discloses a shift effluent cooler (Figure 1, 61: applicant's WGS heat exchanger) receiving a shift effluent stream (Figure 1, 60: applicant's gaseous reformat) from a shift reaction zone (Figure 1, 44: applicant's WGS reactor) that heats and partially vaporizes, by indirect heat exchange, a deionized water stream (Figure 1, 40) (Col. 12, in 16-27). The cooler works to decrease the temperature of the effluent stream to effective oxidation conditions and to heat and partially vaporize the water stream.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included a shift effluent cooler as taught by Towler et al. to cool the shift effluent stream to effective oxidation conditions between the water-gas-shift reactor and preferential oxidation unit as taught by Eggert et al.

Claim 26 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. (*Characteristics of an Indirect-Methanol Fuel Cell System*) in view of Okamoto (US 2002/0177016 A1) and further in view of Grasso et al. (US 2001/0004500), as evidenced by Baukal, Jr. (Heat Transfer in Industrial Combustion).

The Eggert reference teaches the elements of claim 21 but fails to disclose a heat exchanger to preheat the anode exhaust before it enters a combustor with the combustor exhaust.

The Grasso reference teaches an anode exhaust heat exchanger (Figure 1, 44: applicant's anode exhaust preheat heat exchanger) receiving an anode exhaust stream (Figure 1, 42) and passing it in a heat exchange relationship with oxidized anode exhaust (Figure 1, 46: applicant's combustor exhaust) before sending the anode exhaust to the a burner (Figure 1, 40" applicant's combustor).

Baukal, Jr. teaches that preheating fuel fed to a combustor increases the adiabatic flame temperature. This, in turn, increases the radiation and convection from the combustion products because they are at higher temperatures (which increases radiation), the transport properties change, and the product gas velocity increases (which increases convection) (8.4.1.4 Fuel Temperature).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included in the fuel cell system as disclosed by Eggert et al. the anode exhaust heat exchanger and anode exhaust burner as disclosed by Grasso et al. in order to increase the heat transfer from combustion products to the load. The use of burner exhaust as the heating fluid in a heat exchanger that heats the fuel fed to the burner for combustion is an economically advantageous strategy that reduces the overall utility cost associated with this power plant by decreasing the amount of material or equipment that would be needed to provide heat and for efficient thermal management within the fuel cell power plant.

Claim 27 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. (*Characteristics of an Indirect-Methanol Fuel Cell System*) in view of Okamoto (US 2002/0177016 A1) and further in view of Van Dine et al. (US 2003/0027025 A1).

The Eggert reference teaches the elements of claim 21 but fails to disclose a water injector for providing the required steam to the primary reactor.

The Van Dine reference teaches the injection of liquid phase water into a heated hydrocarbon stream. The heat of the hydrocarbon stream, which has been passed through a heat exchanger, vaporizes the water to provide a hydrocarbon/steam mixture. These heating and injection steps can be repeated to reach the desired S:C (pg. 2, [0026], [0029]). Any injected water that is not vaporized by the heat in the hydrocarbon stream would be vaporized in the subsequent heat exchanger.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included a water injector as taught by Van Dine et al. to put water in the reactant stream before entering the super heater in order to provide the desired S:C at the reformer.

Claim 28 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. (*Characteristics of an Indirect-Methanol Fuel Cell System*) in view of Okamoto (US 2002/0177016 A1) and further in view of Bloomfield (3,982,962), as evidenced by Mugerwa et al. (*Fuel Cell Systems*).

Figure 1 of the Eggert reference shows a reformer (applicant's primary reactor) with a reactant stream of steam and fuel that generates reformat. The reformat is fed to a PEM fuel cell stack (pg, 1327) that uses the reformat to produce electrical power. The fuel cell stack is water cooled, and the water and thermal management of the fuel cell maintains water self-sufficiency of the system, including water for steam reformation (pg. 1330). An evaporator (applicant's primary reactor heat exchanger) for transferring heat energy from the reformat to the reactant steam is positioned between the reformer and a water-gas-shift reactor. A catalytic burner (applicant's catalytic combustor) burns anode exhaust, fuel, and air to supply heat energy to the reformer and super heaters (applicant's superheat heat exchanger) for superheating the fuel and steam before they are mixed and reacted in the reformer. Eggert also teaches a CO clean-up unit consisting of a water-gas-shift reactor and preferential oxidation unit (pg 1327). It is noted that applicant requires a high temperature proton exchange membrane fuel cell (HT-PEMFC); this requirement is met in the Eggert reference's proton exchange membrane (PEM) (pg. 1327). An HT-PEMFC employs a proton exchange membrane. The Eggert reference fails to disclose the addition of compressed air to the superheated stream or a heat exchanger between the primary reactor and WGS reactor.

Okamoto teaches a stream of air supplied to the reformer (Figure 1, 6: applicant's primary reactor) from a compressor in the air supply device (Figure 1, 11). The compressed air promotes water vapor reformat reactions and partial oxidation reactions (pg. 2, [0027]). Although the diagram does not show the superheated stream

and compressed air stream being mixed before entering the reformer, they must be mixed prior to use within the reformer.

The Bloomfield reference teaches a fuel cell power plant containing a fuel cell thermal management portion (Figures 1, 25) in which water flows to cool the fuel cell. This water is at least partially vaporized (turned to steam) in this process (Col. 5, ll. 28-33). This steam then flows through several heat exchange operations including a heat exchanger (Figures 1, 72: applicant's primary reactor heat exchanger) positioned between the steam reforming reactor (Figures 1, 18: applicant's primary reactor) and the shift converter (Figures 1, 16: applicant's WGS reactor) that transfers heat from the processed fuel (Figures 1, 70: applicant's reformate) to the steam stream from the thermal management portion of the fuel cell before it is mixed with fuel and fed to the steam reforming reactor. Mugerwa teaches that the reformer and fuel cell generate heat that can be used elsewhere in the fuel cell system; good design must ensure a high degree of heat integration, thereby enabling maximum fuel cell system efficiencies (Pg. 228-229).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to mix the superheated reactant stream containing fuel and steam from the super heaters as taught by Eggert et al. with compressed air as taught by Okamoto in order to promote water vapor reformate reactions and partial oxidation reactions and to include a primary reactor heat exchanger for preheating the reactant stream in order to maximize fuel cell efficiencies as taught by Mugerwa.

(10) Response to Argument

Regarding items VII.B.1 and VII.C of the Appeal Brief: Appellant argues that neither Grasso nor Bloomfield teach an HT-PEMFC but rather teach conventional fuel cells. The present specification defines high temperature as "between about 100°C and 1500°C," and states that conventional fuel cells "operate at about 60°C to about 900°C". Given no definition of the term "about" it is considered that "about 100°C" and "about 900°C" at least overlap. Additionally, Appellant argues that one of ordinary skill in the art would not have been motivated to recycle air from the condensers into the compressors because the Mugerwa only teaches generally the advantage of interaction between the fuel cell and subsystems. Appellant asserts that this is an "obvious to try" rationale. However, the integration of systems within a plant is a very common skill in plant design and/or optimization, and the recycle of air is a common strategy used in order to reduce utility costs by using the temperature and/or pressure of the air instead of releasing it as an effluent and then having to heat or pressurize another stream "from scratch."

Regarding item VII.D of the Appeal Brief: Appellant argues that the "examiner utilizes a 'capable of' test, which the examiner created by interpreting the claim language 'adapted to' to mean 'capable of'." According to MPEP 2173.05(g), "adapted to" is a functional limitation. There is no reason to believe that the prior art WGS reactor could not be adapted to heat the steam before being used in the primary reactor with heat energy from the reformatte, and Appellant has provided no evidence to the contrary. Again, Appellant asserts that one of ordinary skill in the art would have to

"experiment blindly with numerous plant parameters to achieve the claimed invention" however, heat integration is very common in the art of plant design and optimization as a strategy to reduce utility costs as well as to make the waste streams more environmentally friendly and increase efficiency.

Regarding item VII.E of the Appeal Brief: Appellant argues that the rejection of Claims 7 & 8 utilizes hindsight. Grasso teaches "adequate water" is supplied to the fuel cell. "Adequate" is interpreted as meaning both in quantity and quality.

Regarding item VII.F of the Appeal Brief: Appellant argues that no bypass circuit is taught because such a circuit inherently requires a diversion device. However, this is not a limitation of the claim and bypass circuits do not necessarily require diversion devices; they may operate under the pressure of the stream.

Regarding item VII.G and VII.H of the Appeal Brief: Appellant argues that Egged does not teach an HT-PEMFC, which, as defined by Appellant, "operates at around 100°C to around 1500°C." However, Eggert's fuel cell operates at 80°C, which is "about 100°C." Additionally, Eggert teaches superheating of the reactant stream. The reactants fed to the reformer must be mixed for the reforming reaction to take place.

Regarding item VII.I of the Appeal Brief: Van Dine teaches water injected into a reactant stream that has passed through a heat exchanger. This can be repeated to reach the desired steam to carbon ratio, thus injecting water before the reactants enter a heat exchanger. Any water not vaporized by the heat of the reactant stream upon injection would be vaporized in the subsequent heat exchanger. Eggert teaches a superheated heat exchanger.

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

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Conferees:

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